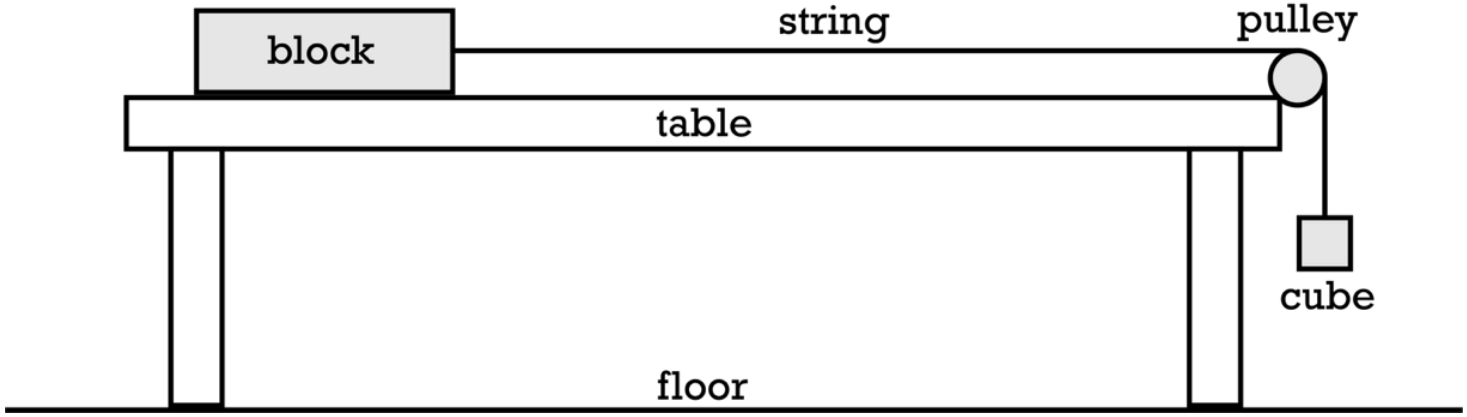
Mr.p - Green Screen: 1/100, f3.2, iso 160, EV+0.0, Auto Focus, H4n INPUT @ 95% gain.
BBB 1/60, f5.6, iso 640, WB Use Grey Card, Manual Audio at level 11, focal length ½ way to ∞. H4n INPUT @ 95% gain.
BBB Check Horizontal Level & Billy's Lights!! Middle line at bottom 1/3 of desk & remember Billy and Bo chair locations!
Video Title: 518 – Newton's Second Law - AP Physics 1 - Dynamics Review Supplement

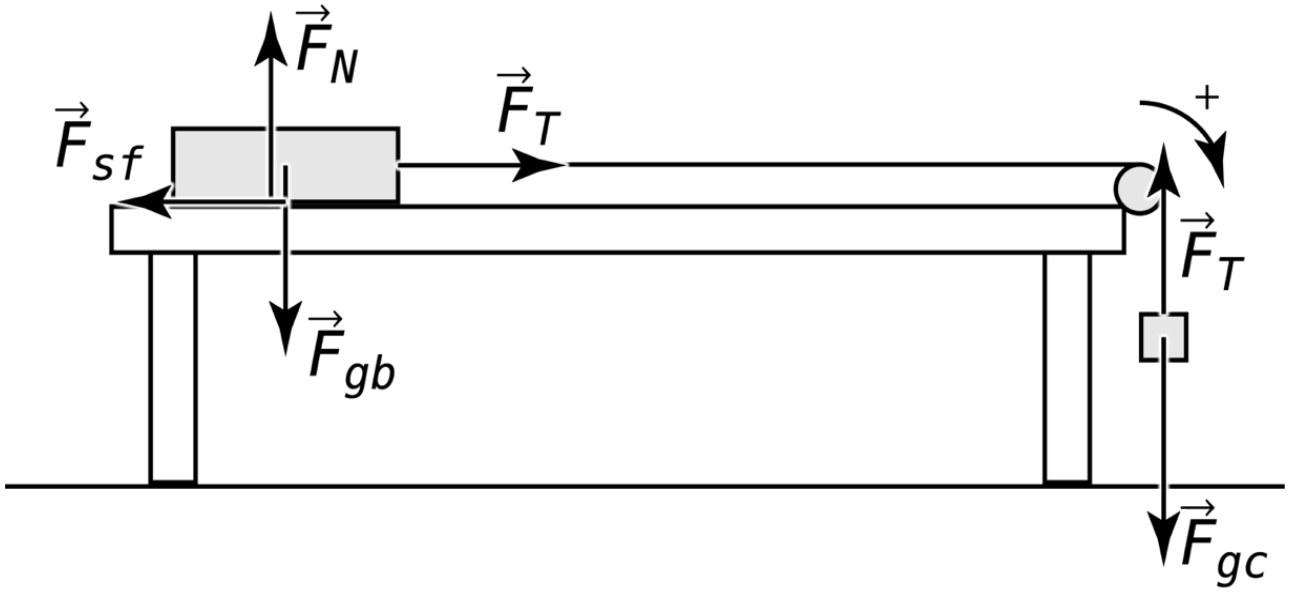
Mr.p: Good morning. Let's do three multiple-choice problems about friction to review for the AP Physics 1 exam. This is a part of my AP Physics 1 Ultimate Review Packet, so, please, consider signing up at Ultimate Review Packet dot com for the full review. [♪ Flipping Physics ♪] Billy, please read question one.



Billy: Absolutely! … Question 1. As shown, a block of mass m sub b on a table is attached to a string which goes over an ideal pulley and is attached to a cube of mass m sub c. The block and cube are currently at rest. If the coefficient of static friction between the block and the table is mu sub s, the magnitude of the force preventing the block from accelerating is best

described by … choice A, coefficient of static friction times the mass of the block times acceleration due to gravity, … choice B, coefficient of static friction times the mass of the cube times acceleration due to gravity, … choice C, the quantity of the mass of the cube plus the mass of the block all times acceleration due to gravity, … or choice D, the mass of the cube times acceleration due to gravity.

Mr.p: Thank you Billy. Bobby, please begin solving the problem.



- Bobby: Well, … we start with the free body diagram, of course.
- Billy: Actually, free body diagrams, plural, because we need a diagram of all the forces acting on the block, … and a diagram of all the forces acting on the cube.

- Bobby: Yeah, that makes sense. … There is a force of gravity acting down on the block and a force of gravity acting down on the cube. … There is a force of tension on each end of the string, one acting to the right on the block and one up on the cube. … There is a force normal from the table acting up on the block. … And a force of static friction from the table acting to the left on the block.

Mr.p: Bo, please continue solving from here.

- **Bobby: {working on the problem}**
- Bo: Sure. … What are we solving for?

- Billy: The magnitude of the force preventing the block from accelerating.
- Bo: … So, the force of static friction acting on the block from the table?
- Billy: Yep!
- Bo: Okay. We need to sum the forces to solve for the force of static friction. … We could sum the forces on the block in the x-direction to solve for the relationship between the force of static friction and the force of tension and then sum the forces on the cube in the y-direction and combine

equations.

- Billy: Actually, it will take fewer steps if we sum the forces on the block and the cube simultaneously. We just need to define the positive direction as to the right on the block and down on the cube in order to do that.
- $\sum F_{+} = F_{gc} - F_T + F_T - F_{sf} = ma_{+} = m(0) = 0 \Rightarrow F_{sf} = F_{gc} = m_c g$
- Bo: Sure, we can do it that way. Let's sum the forces on the block-cube system in the positive direction. … That equals the force of gravity on the cube which is positive because it is in the positive direction, … minus the force

of tension acting on the cube because it is opposite the positive direction, … plus the force of tension acting on the block which is positive because it acts in the positive direction, … minus the force of static friction acting on the block because, again, it is acting opposite the positive direction. … The two forces of tension cancel out. … The acceleration of the block-cube system in the positive direction is zero because it's not moving. … That means the force of static friction equals the force of gravity acting on the

cube, and that equals the mass of the cube times the acceleration due to gravity. So, choice D is the correct answer choice.

- Bobby: … Uh, … I got a different answer. I got choice A as correct.
- Bo: How?
- $\sum F_y = F_N - F_{gb} = m_b a_y = m_b(0) = 0 \Rightarrow F_N = F_{gb} = m_b g$
- $F_{sf} = \mu_s F_N = \mu_s m_b g$
- Bobby: I summed the forces in the y-direction on the block and got force normal minus force of gravity on the block. The acceleration of the block in the y-direction is zero, so force normal

equals force of gravity on the block or mass of the block times acceleration due to gravity. … And force of static friction equals the coefficient of static friction times force normal. So, the force of static friction equals the coefficient of static friction times the mass of the block times the acceleration due to gravity. Which is choice A, not choice D.

- Bo: … Right. …
- Billy: Uh … They cannot both be correct, right?
- Bo: Right. This is not one of the questions

which says it has two correct answers.

- Billy: Yeah.

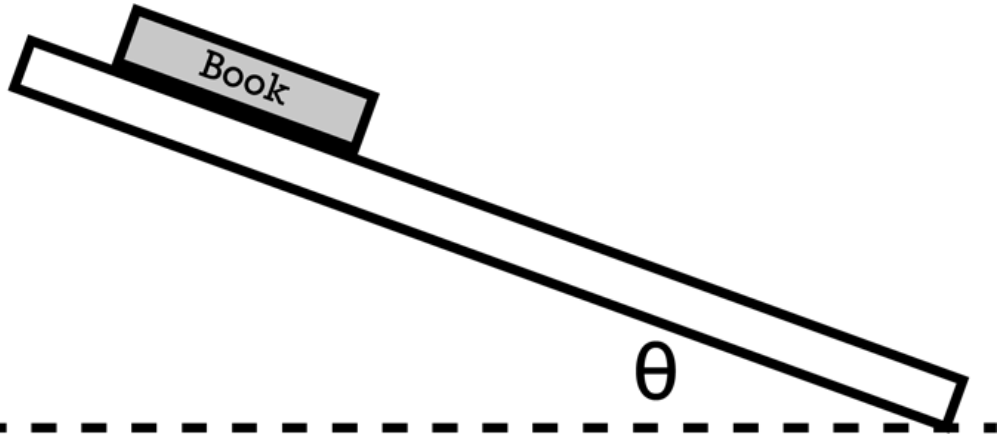
Mr.p: … Does the force of static friction equal the coefficient of static friction times force normal?

- Billy and Bo: … Yes?
- Bobby: No. … The force of static friction is less than or equal to the coefficient of static friction times force normal.
- Billy and Bo: Oh!
- Bobby: What I found is the **maximum** force of static friction. Right now in the problem, the force of static friction is less than its maximum

value. And we have to solve for the force of static friction the way Bo did. That makes sense.

- Billy and Bo: Yeah.

Mr.p: Yep. … Billy, please read the next question.

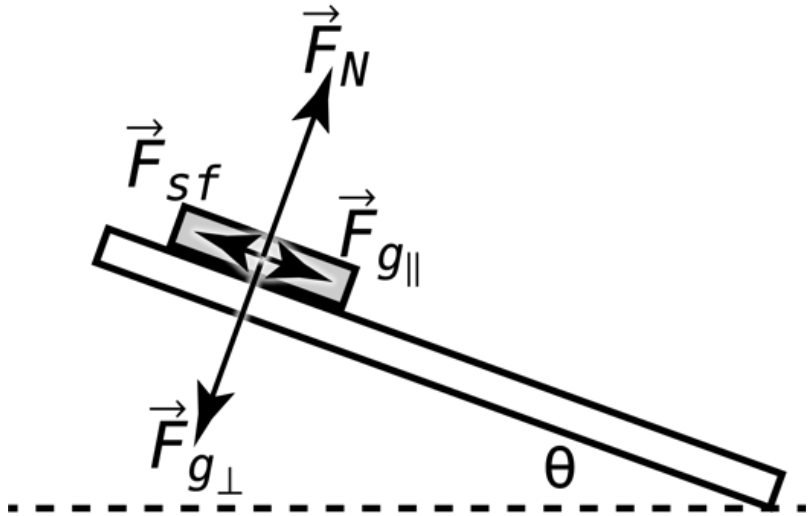


Billy: Certainly! … Question 2. A book with mass m is at rest on an incline of angle theta as shown. If the coefficient of static friction

between the book and the incline is mu sub s, and the coefficient of kinetic friction between the book and the incline is mu sub k, which expression best represents the force of friction currently acting on the book? … Choice A, the coefficient of static friction times mass times acceleration due to gravity times the cosine of the incline angle, … choice B, the coefficient of kinetic friction times mass times acceleration due to gravity times the cosine of the incline angle, … choice C, mass times acceleration due to gravity times the cosine of the incline

angle, … or choice D, mass times acceleration due to gravity times the sine of the incline angle.

Mr.p: Bo, please solve this one.



$$\sum F_{\parallel} = F_{g_\parallel} - F_{sf} = ma_{\parallel} = m(0) = 0$$

$$F_{sf} = F_{g_\parallel} = mg\sin\theta$$

- **Bobby: {Working on the problem.}**

- Bo: … Let's start with the free body diagram of the forces acting on the book. … The force of gravity is … well, if this free body diagram were the answer to a free response question, I would have the force of gravity straight down in my free body diagram, however, because this is a multiple-choice problem and I know I need the components of the force of gravity, I am going to start with the force of gravity parallel down the incline and the force of gravity perpendicular down and perpendicular to the incline.

- Billy: Right. You never, on an AP physics exam, put components of forces in a free body diagram which is an answer on a free response question, however, it is fine to do on a multiple-choice question.
- Bo: That's what I said.
- Billy: I was just supporting you.
- Bo: Right. Thanks. … Now we can sum the forces on the book in the parallel direction. … Force of gravity parallel minus force of static friction … and that equals mass times acceleration in the parallel direction. …

However, because the book is at rest, the acceleration of the book in the parallel direction is zero. … That means the force of static friction equals the force of gravity parallel … and that equals mass times acceleration due to gravity times the sine of the incline angle. … So, choice D is the correct answer choice.

- Billy: How do you know the equation for the force of gravity parallel?
- Bo: It is one of the equations mr.p told us we should memorize for the exam.

- Billy: Okay, … But how do you remember if force of gravity parallel uses sine or cosine?
- Bo: Oh, easy. If the incline angle were zero, the force of gravity parallel would be zero, and the sine of zero degrees equals zero. So, it must be sine in the force of gravity parallel equation.
- Billy: That makes sense. The cosine of zero degrees equals 1, so it would not be cosine. Thanks Bo.
- Bo: You're welcome Billy. … So, yeah, choice D is the correct answer choice.

- Bobby: … Uh, … I got a different answer. I got choice A as correct.
- Bo: How?
- $\sum F_{\perp} = F_N - F_{g_{\perp}} = ma_{\perp} = m(0) = 0 \Rightarrow F_N = F_{g_{\perp}} = mg\cos\theta$
- $F_{sf} = \mu_s F_N = \mu_s mg\cos\theta$
- Bobby: I summed the forces in the perpendicular direction on the book and got force normal minus force of gravity perpendicular equals mass times the acceleration in the perpendicular direction. And the acceleration in the perpendicular direction of the book is zero because it's not

moving. That means force normal equals force of gravity perpendicular which equals mass times acceleration due to gravity times cosine of the incline angle.

- Billy: Yep. Cosine!
- Bobby: And force of static friction equals the coefficient of static friction times force normal. And we can substitute mass times acceleration due to gravity times cosine theta in for force normal to get that the force of static friction equals the coefficient of static friction times mass times acceleration due to gravity

times the cosine of the incline angle. Which is choice A, not choice D.

- Bo: … Huh.
- Bobby: Yeah.
- Billy: … Really? Do you both not see it?
- Bobby and Bo: See what?
- Billy: The force of static friction does not **equal** the coefficient of static friction times force normal, the force of static friction is **less than or equal** to the coefficient of static friction times force normal. … We just did this.
- Bobby: Oh right, we did just do this.

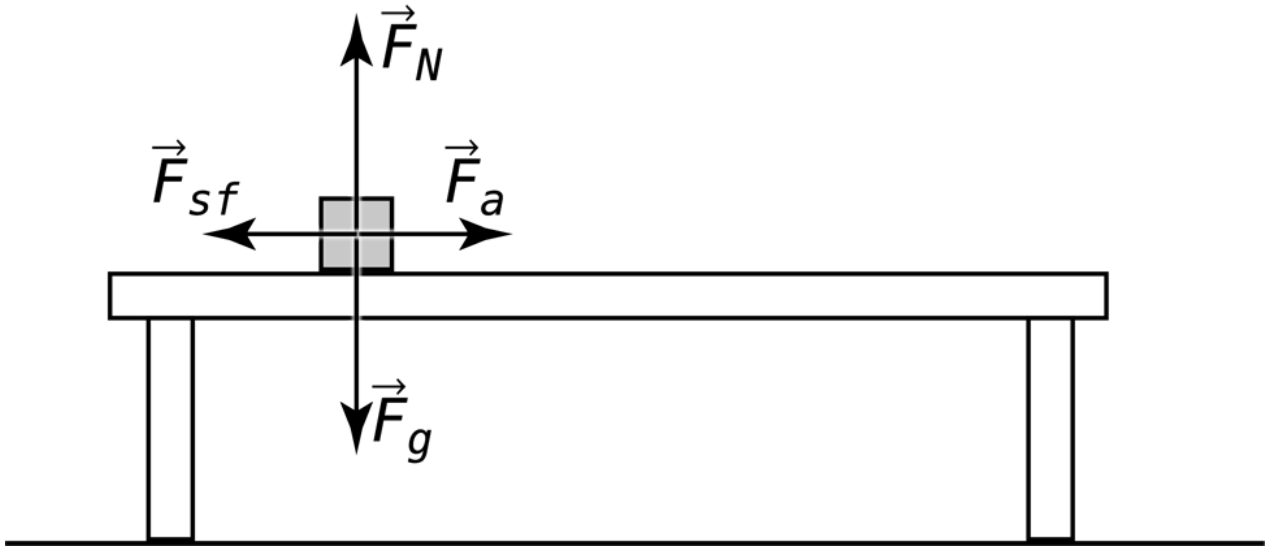
- Bo: Yeah. The force of static friction **maximum** equals the coefficient of static friction times mass times acceleration due to gravity times cosine theta and the angle must not currently be large enough for the force of static friction to be at its maximum value. That makes sense.

Mr.p: Yep. Bo, please read the last question.

Bo: Question 3. … A 20 kilogram block is at rest on a table. A horizontal force of 140 newtons is applied to a block, however, it is not enough to move the block. Which of the following best

describes what we know about the coefficient of static friction between the block and the table? … Choice A, the coefficient of static friction is greater than or equal to 0.7, … choice B, the coefficient of static friction equals 0.7, … choice C, the coefficient of static friction is less than or equal to 0.7, … or choice D, the coefficient of static friction equals 1.4.

Mr.p: Thank you Bo. Billy, please solve this one.



$$\sum F_y = F_N - F_g = ma_y = m(0) = 0 \Rightarrow F_N = F_g = mg$$

$$\sum F_x = F_a - F_{sf} = ma_x = m(0) = 0 \Rightarrow F_a = F_{sf} = \mu_s F_N = \mu_s mg$$

$$\Rightarrow \mu_s = \frac{F_a}{mg} = \frac{140}{(20)(10)} = 0.7$$

- Billy: Absolutely! … Well, we start with the free body diagram of the forces acting on the block. The force of gravity is down, the force

normal is up, the force applied is horizontal, … let's make it to the right, and the force of static friction is to the left. … And now we can sum the forces in the y-direction. Force normal minus force of gravity equals mass times acceleration in the y-direction. … Acceleration in the y-direction equals zero. So, force normal equals force of gravity or mass times acceleration due to gravity. … And now we can sum the forces in the x-direction. Force applied minus force of static friction equals mass times acceleration in the x-direction. …

Acceleration in the x-direction also equals zero. So, force applied equals force of static friction which equals the coefficient of static friction times force normal or the coefficient of static friction times mass times acceleration due to gravity. … Rearranging the equation gives us the coefficient of static friction equals force applied divided by mass times acceleration due to gravity. … Substituting in numbers gives us 140 divided by the quantity 20 times 10, … 14 over 20 or 7 over 10 or 0.7. … So, the coefficient of static friction equals

0.7, the correct answer is choice B.

- Bobby and Bo: {turn and look and wait}
- Billy: What?
- Bobby and Bo: {still waiting}
- Billy: Oh, I made the same mistake as we did before, right?
- Bobby and Bo: Yep.
- Billy: The force of static friction does not **equal** the coefficient of static friction times force normal it is **less than or equal** to the coefficient of static friction times force normal. … That means … well, … what we know

about this coefficient of static friction is that it is greater than or equal to 0.7. The correct answer is choice A.

- Bobby: … So, I get all that, but why does that mean the coefficient of static friction is greater than or equal to 0.7? Why wouldn't it be less than or equal to 0.7?

{switch perspective}

$$F_a = F_{sf} = 140N \;\&\; F_N = F_g = mg = (20)(10) = 200N$$

$$F_{sf} \leq \mu_s F_N \Rightarrow 140 \leq \mu_s (200) \Rightarrow 0.7 \leq \mu_s \Rightarrow \mu_s \geq 0.7$$

- Mr.p: That's a fair question Bobby. One way to look at it is that we have found the minimum

coefficient of static friction necessary to keep the mass from moving. If the coefficient of static friction were larger than 0.7, the mass would still not move.

- **Bo: (But how do we know we found the minimum and not the maximum coefficient of static friction?)**
- Mr.p: Okay. Uh, … let's solve it slightly differently. We know the force applied equals the force of static friction, so the force of static friction in this example equals 140 newtons. … And the force normal equals the force of

gravity which equals mass times the acceleration due to gravity which equals 20 times 10 or 200 newtons. … Then we can use the equation for the force of static friction to solve for the coefficient of static friction. Force of static friction is less than or equal to the coefficient of static friction times force normal. … Substituting in numbers means 140 is less than or equal to the coefficient of static friction times 200. … Dividing both sides by 200 gives us 0.7 is less than or equal to the coefficient of static friction. … In other words, the coefficient

of static friction is greater than or equal to 0.7 in this problem.

- **Bo: (That makes sense. Thanks mr.p.)**
- Mr.p: You are welcome Bo. … So, notice this was 3 questions which all had specifically to do with the less than or equal to sign in the force of static friction equation. … All 3 of these multiple-choice questions are different, however, they all test your knowledge of that specific part of that single equation. So, realize the force of static friction equation is an important concept to understand and, there

are many ways to test your knowledge of a single concept. … Thank you very much for learning with me today, I enjoy learning with you.